Design of Experiment to Explore Inside the LANSCE H^- Ion Source with Laser Absorption Techniques

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Abstract. The Los Alamos Neutron Science Center (LANSCE) H^- ion source (LHIS) has provided stable output for decades of LANL mission needs. While several in-house improvements have been made to its stability and lifetime, its maximum beam output has remained the same at ~14 mA. While operationally well understood, the internal relationship between the LHIS plasma, cesium distribution (the catalyst for producing H^- ions), and produced H^- beam remains a mystery, only explored indirectly with models. We will develop fast, accurate, and non-invasive diagnostics techniques to measure the Cs and H^- densities inside LHIS. These diagnostics are based on optical absorption spectroscopy that have been developed in the last decade for fusion based H^- ion sources that can readily be applied to the accelerator based LHIS. A refined form of optical absorption spectroscopy, the laser absorption technique (LAT), utilizes lasers tuned to a given atomic species to measure its density. In this case a laser tuned to the D2 line of cesium will be used to determine its density inside LHIS. Similarly, a refined version of LAT called the cavity ring-ring down spectroscopy (CRDS) technique utilizes a laser tuned to H^- photo-detachment to measure the H^- densities at inside LHIS. With successful development of these diagnostic techniques, any hidden or dormant capabilities in LHIS will be found and capitalized upon, both in its modelling and operation. Also, its potential benefit to LANSCE and LANL future needs will be realized. More generally, this will be the first use of these plasma diagnostic techniques on an accelerator based H^- ion sources. We will present on the preliminary status of the diagnostic setup.

INTRODUCTION: THE H^- ION SOURCE AT LANSCE

The Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory provides an 800 MeV H^- Beam that is used for multiple research experiments [1]. The H^- beam is created inside a high frequency (120 Hz), high duty factor (10%, 833 μs) tungsten filament-plasma driven, cesiated surface-conversion, multi-cusp ion source [2]. Figure 1 demonstrates the nominal operation of this LANSCE H^- ion source (LHIS) in more detail.

LHIS has been used for decades to meet LANSCE experimental needs. While LHIS is well understood operationally, qualitatively, and conceptually, little is known about many internal parameters. In particular the quantitative cesium density and H^- beam density inside the H^- Ion Source is not known. A new research project is being developed to establish two new diagnostic capabilities inside LHIS based on optical absorption spectroscopy to measure these quantities. In the short term, this read-back diagnostic will optimize the present LHIS performance, as well as assist and validate LHIS models [3, 4]. Long term, it will provide valuable H^- ion source data for the international accelerator community, and demonstrate the capability of this diagnostics for present and future accelerator based H^- ion sources.

This paper will lay out the procedure and plans quantify the Cesium and H^- densities inside the H^- ion source using laser absorption spectroscopy.

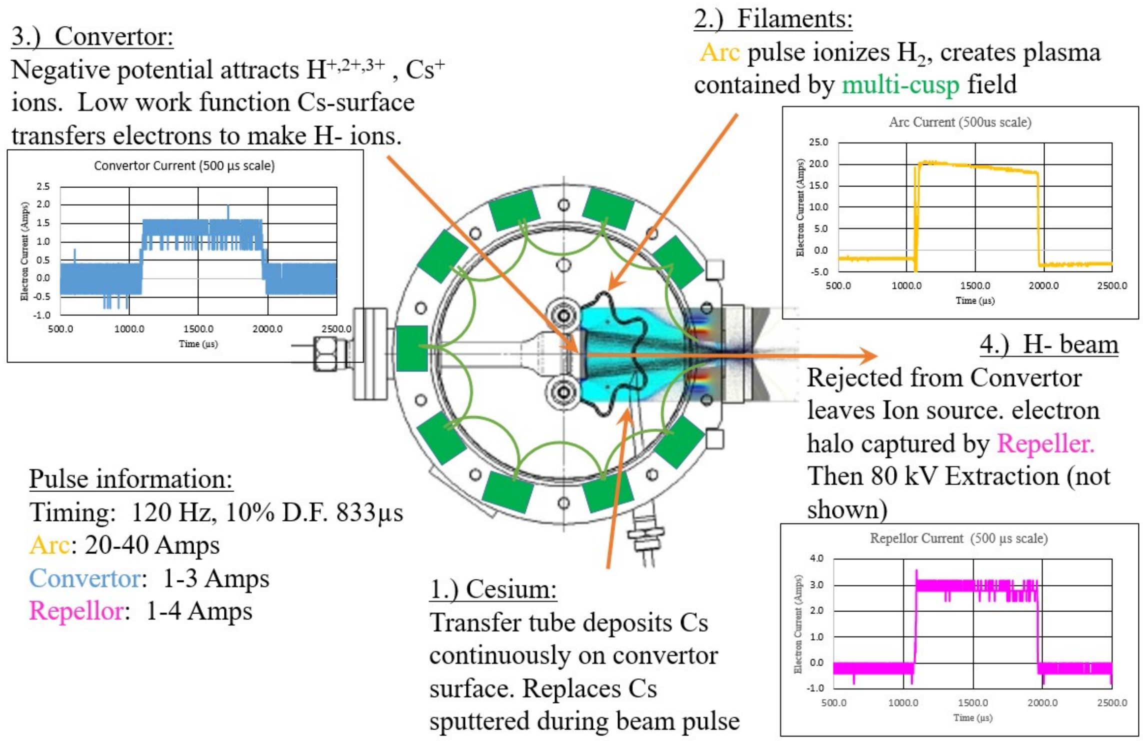

FIGURE 1. Animation demonstrating the basic operation of LHIS. Follow steps 1-4 for basic operational description.

LASER ABSORPTION TECHNIQUES

Cesium Quantification and control

While cesium is the catalyst for creating H^- ions due to its low work function [5], it has other effects that must be mitigated. Cold cesium deposits may produce arc current shorts, and ionized cesium may cause plasma instabilities [6]. These in turn can lead to unstable ion source conditions, thus unstable beam output for LANSCE mission needs. Currently, the cesium density inside LHIS is unknown. Current model estimates [3, 4] based on simple vapor pressure calculations estimate ~10^{10} cm^{-3} (~10^{16} cm^{-3}) near the walls (transfer tube). *Laser Absorption Techniques* (LAT) are a non-invasive, fast measurement that can directly monitor the cesium density inside LHIS in real time [7]. LAT is a form of optical absorption spectroscopy that focuses on high sensitivity and precision for a given atomic state. Figure 2 gives a basic diagram of LAT setup. Plans are to use a diode laser tuned to the D2 line of cesium (852.1 nm) to measure the cesium density inside LHIS. The laser power was chosen to be 25 mW, which will be able to be attenuated to measure the wide range of estimated Cs densities of (10^{10} – 10^{16} cm^{-3}). Knowing the real-time cesium density inside LHIS before, during, and after the beam pulse will allow for the minimum-optimization of the amount of cesium deposited into LHIS from the transfer tube, which will maximize H^- beam output while avoiding LHIS instabilities related to over-cesiation effects.

H^- Beam Measurement

Currently at LANSCE, the H^- beam is measured downstream from LHIS at LANSCE. The internal LHIS properties of the H^- beam, *i.e.* the production/destruction of the H^- ions inside LHIS, has never been experimentally quantified. A new model estimates a mean free path extinction of 20 cm [8]. An enhanced version of LAT, called *Cavity Ring Down Spectroscopy* (CRDS) can be utilized to calculate the density of H^- ions inside LHIS at several points, from H^- ion formation to extraction. CRDS enhances LAT by introducing highly reflective mirrors to the LAT setup [9]. Figure 2 gives a basic diagram of CRDS setup. The mirrors allow for multiple pass through of laser light tuned to measure the small cross section (~10^{-21} m^2) of the H^- photo-detachment process (~0.75 eV). This ultra-sensitive technique can be used to measure the line-of-sight integrated H^- density at several points inside LHIS, in particular as it converses the plasma (convertor to beam extraction). The signal is an exponential decay curve related to the density of the material under test, as well as the mirrors' reflectivity. Since the decay time can be measured with and without plasma, background/average values are directly obtained, and complicated calibration procedures can be avoided. The type, power, and wavelength of laser to be used for the H- density is under development. Knowing the H^- density profile inside LHIS will allow for capitalization of the LHIS performance, as well as fast-track innovative improvements to its research & development.

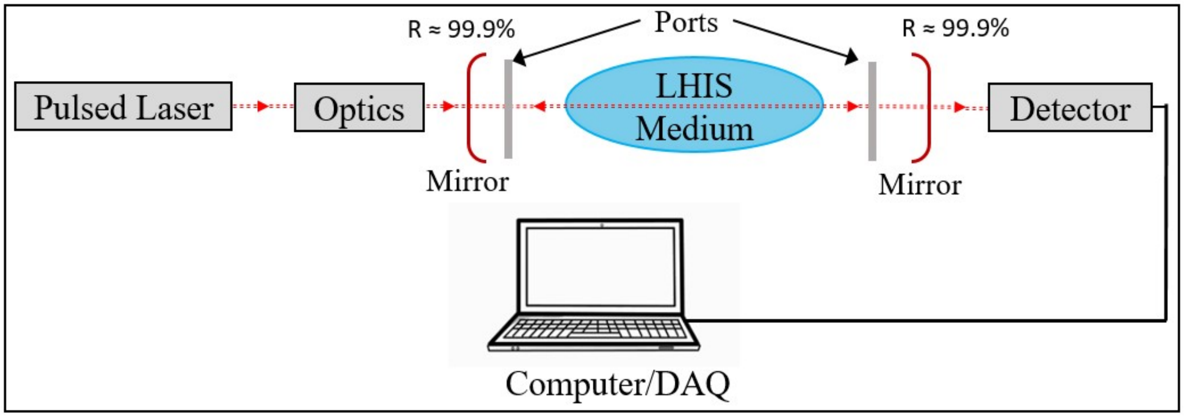

FIGURE 2. Basic setup of the diagnostics. Removing (Adding) the Mirrors gives LAT (CRDS) setup.

PRELIMINARY SOURCE MODIFICATIONS AND LABORATORY SETUP

Side-plate Modification

The first phase modification of LHIS has been completed to undertake the measurement. Two optical port paths have been installed on the ion source, and are showed in fig. 3. The port locations were chosen as not interfere the present vacuum ring, water line, and multi-cusp magnet configurations inside the LHIS side-plates. The front port will be used to measure the cesium density at the transfer tube, as well as the H^- density as the beam traverses the ion source. The top port will be used to quantify cesium densities near the walls of the ion source. Measuring the cesium density at the transfer tube via the front port and near the walls via the top port will help shed light on what role foreground (transfer tube) and background (walls) cesium densities play in the H beam density formation [10]. For the H^- density, the front port is large enough (2.5 cm) to measure several line of sight H^- densities, such as observing the neutralization losses of H^- beam as it traverses the ion source. Care will need to be taken when doing measurements via the front port, as the tungsten filament blocks partially of the line-of-sight view through the ion source.

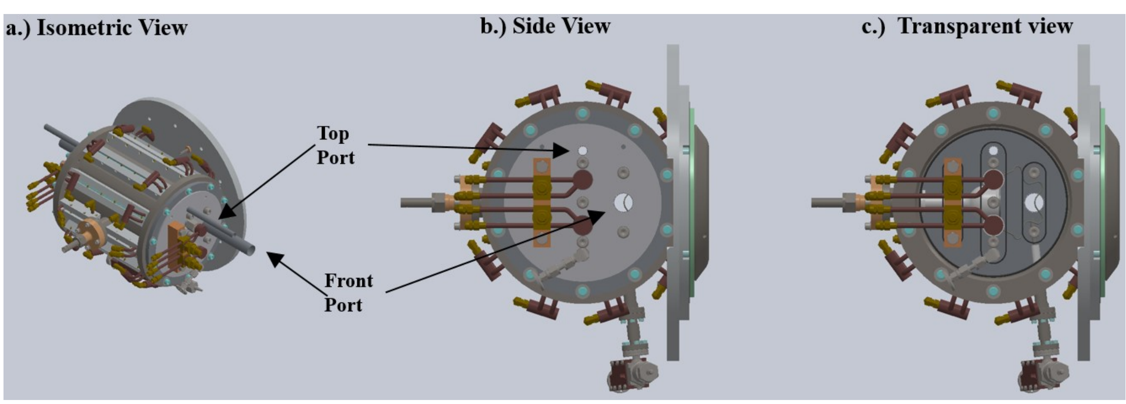

FIGURE 3. The first modification LHIS with side-plate ports installed. The right view (c) gives a transparent view, where side plate is transparent so that underlying vacuum and water cooling O-rings are shown. Cesium density will be measured using both the top and front ports. The H^- density measurements will be measured using the front port, with the ability to take several data points within the port.

Laboratory Setup

The fully proposed laboratory setup is shown in Fig. 4. The main technical challenges and their response will be discussed. The optical ports have the potential to become contaminated both from cesium as well as by tungsten, which evaporates from the filaments inside the ion source. This is addressed by gate valves that will be installed on each optical port. These serve two purposes: prevent window contamination during initial source processing, and to allow manipulation and troubleshooting of optical port equipment. Having the ability to manipulate optical port equipment introduces an additional challenge in that the small portion of vacuum plumbing between the optical port and the gate valve will require evacuation before the gate valve can be opened. Angle valves will be installed to allow for roughing out of this small interface cavity.

It is important to note that the initial diagnostic setup has no high voltage extraction, which is -80 kV for the LHIS ion source. This is to avoid safety hazards related to high voltage, and to keep the initial trial and error development stages of the diagnostic simple, *i.e.* benchtop. Once the diagnostic is establish on the test bench, it will be tested with high voltage beam injection on the LANSCE H- Ion Source Test Stand [11]. This will also allow for independent measurement with and without back-streaming effects, which are present with high voltage beam extraction.

Downstream of the ion source, an additional optical port assembly will be installed to allow for cesium and H^- measurements external to the ion source. Mechanical vibrations from the vacuum system will be of concern for clean optical signals. A flexibles bellows will be installed between the ion source and the vacuum system assembly to mitigate these effects.

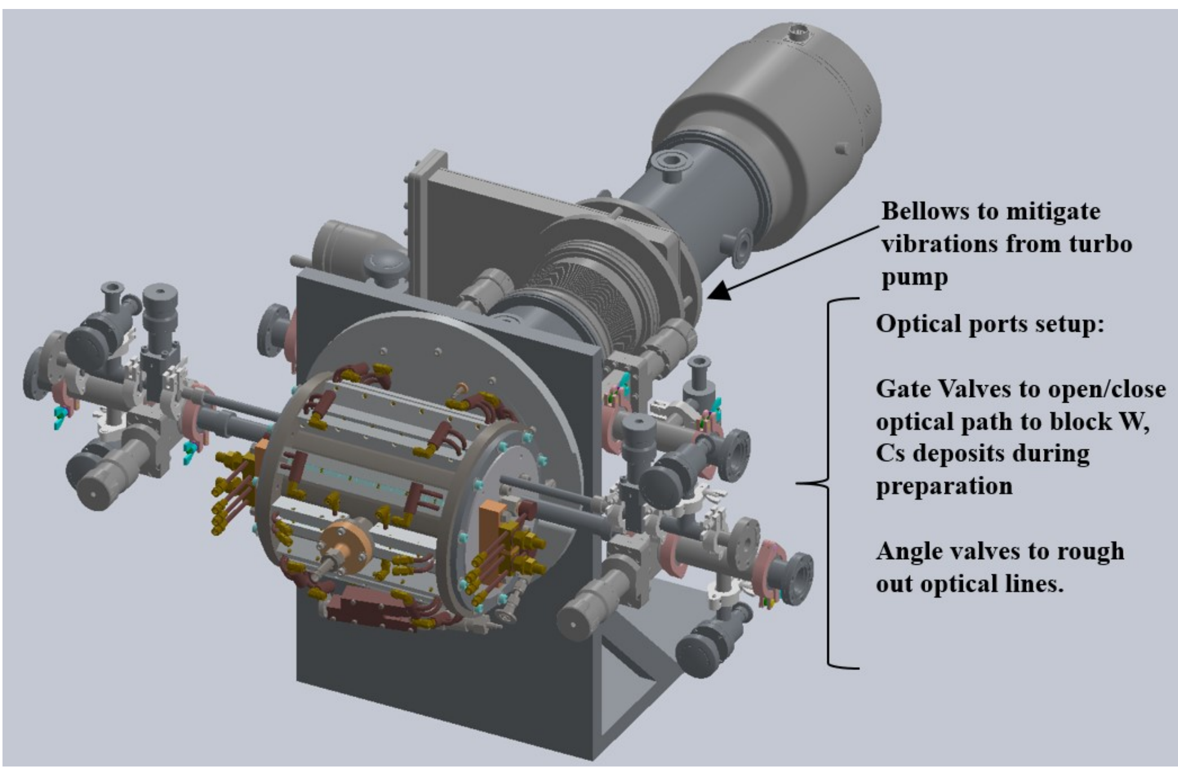

FIGURE 4. The laboratory setup. The main challenges addressed by this setup are given in the text in the figure.

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